MHSMP-75-40N

Slow PBX and Plane Wave Lens Development

J. A. Crutchmer

DEVELOPMENT DIVISION

JULY - SEPTEMBER 1975

Normal Process Development
Endeavor No. 219

MASTER

Mason & Hanger-Silas Mason Co., Inc.
Pantex Plant
P. O. BOX 647
AMARILLO, TEXAS 79177
806-335-1581

operated for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under
U. S. GOVERNMENT Contract DA-11-173-AMC-487(A)

Slow PBX and Plane Wave Lens Development

J. A. Crutchmer

DEVELOPMENT DIVISION

July - September 1975
Endeavor No. 219

ABSTRACT

Work has been completed on three each pressable plane wave lens designs. One of these, of the P/040 configuration using pressable Comp B-3 and 76/24 BN/TNT baratol, was completed and reported some time ago. Results of this lens are being reported here for completeness of this report. Work was recently completed on a P/081 lens design using these same materials.

A higher index lens of the P/040 configuration was also recently finalized. This lens design uses PBX 9404 as the fast component and 85/15 BN/TNT baratol as the slow component.

DISCUSSION

PLANE WAVE LENS SPECIFICATIONS

The specifications imposed on pressable plane wave lens are identical to those of conventional cast lenses. These vary somewhat according to lens size.

For both the P/040 and P/081 the specifications are as follows: the trace spread or range of each test fire, defined as the total elapsed time from the first to the last wave emergence, shall be 0.10 μs or less measured over 90% of a diameter on the lens surface; the transit times, measured at the center of the lens face, of all test fired units from a single baratol batch shall agree within 0.10 μs. If these specifications are exceeded a standard Tau test may be applied.

Cast baratol specifications call for a minimum density of 98% TMD. Pressable baratol contains no binder and usually presses to less than 98% TMD. Therefore, minimum density specifications for pressable baratol were lowered to 97% TMD.

PRESSABLE PLANE WAVE LENSES

A mathematical model for the interface contour between the fast and slow components of a plane wave lens was derived by R. J. Slape(*1*). Certain simplifying assumptions were made in the derivation such as point initiation, constancy of detonation velocities within each component, straight line burn paths within each component and burn paths in the slow component perpendicular to the output face of the lens.

This model was first applied to a P/040 plane wave lens using pressable Composition B-3 as the fast component and 76/24 BN/TNT baratol as the slow component. Detonation velocities are 7.9 km/s for Composition B-3

---
(1) Slow PBX Development Quarterly Report by R. J. Slape, July - September 1971.

and 7.6 km/s for the 76/24 BN/TNT baratol. This lens, along with its original and final interface contour equations, is shown in Fig. 1. Several adjustments to the contour were necessary before arriving at the final model. The outer configuration remained unchanged from the initial to the final stage of lens development.

A total of twelve units of the final model of this lens design were fabricated and fired to establish reproducibility of the lens design. Test fire results are summarized in Table I. This table also contains compositional and density data for the baratol used in these lenses. A typical emergence trace is shown in Fig. 2.

A P/081 plane wave lens was designed using these same materials—Comp. B-3 and baratol. This lens is shown in Fig. 3. Eight of these units were fabricated and fired to establish reproducibility. Test fire results are summarized in Table I and a typical output trace is shown in Fig. 2.

HIGHER INDEX LENSES

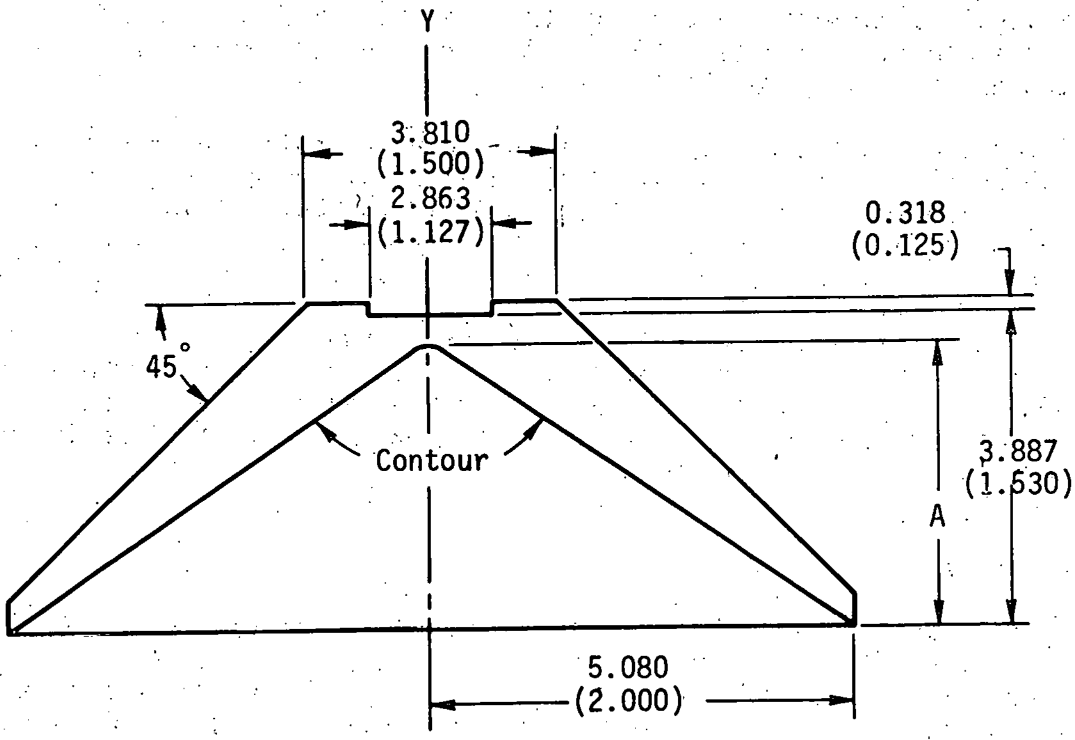
By increasing the difference between the fast and slow component detonation velocities it was possible to produce a much smaller lens. This was accomplished with a P/040 plane wave lens by varying the composition of the baratol to obtain a lower detonation velocity and using PBX 9404 as the fast component. PBX 9404 was chosen for its pressing characteristics and its high detonation velocity (8.8 km/s).

It was found that an 85/15 BN/TNT formulation of baratol would initiate and burn with a steady detonation velocity (3.9 km/s). This baratol formulation was used for the slow component of the higher index P/040 shown in Fig. 4. Ten units of the final model of this lens configuration were fabricated and fired to establish reproducibility. Test fire results, along with the baratol compositional and density data are shown in Table II. A typical output trace is shown in Fig. 2.

It seems reasonable that an extra thickness of material on the output surface of a plane wave lens would improve its simultaneity. The higher index P/040 plane wave lens design was modified to leave an extra 3.2 mm of baratol on the output surface of the lens. This modified higher index P/040 is shown in Fig. 5. Ten units of this lens design were fabricated and fired. Results are shown in Table III.

PRESSURE PROFILE

Pressure profile measurements were made for each of these three lens systems as well as the overcast lenses. The output surfaces of the lenses were coated with a thin layer of sprayed PETN.



Dimensions in Centimeters, English Equivalents in Parentheses.
Contour Equations are in English Units

Original Contour Equation:

$$X^2 = 1.949446Y^2 - 5.589221Y + 4.000$$
$$A = 3.4981\ (1.3772)$$

Final Contour Equation:

$$X^2 = 1.802416Y^2 - 5.373979Y + 4.000$$
$$A = 3.6439\ (1.4346)$$

Fig. 1. P/040 Lens Design Using Pressable Comp B-3 and 76/24 BN/TNT Baratol

Table I. Plane Wave Lens Test Fire Results

Plane Wave Lens No.	Baratol Batch No.	Composition (BN/TNT)	Baratol Piece No.	Density (Mg/m^3)	TMD (%)	Transit Time (μs)	Range[a] (μs)	Tilt (μs)
P/040-1	1060-402B-01	76.3/23.7	99253E4601-10	2.573	97.5	8.113	-0.053	0.113
P/040-2	1060-402B-01	76.3/23.7	99253E4601-09	2.576	97.6	8.182	-0.054	0.009
P/040-3	1335-402B-01	76.0/24.0	27619Y4601-03	2.553	96.9	LOST	LOST	LOST
P/040-4	1335-402B-01	76.0/24.0	27619Y4601-04	2.553	96.9	8.140	0.089	0.014
P/040-5	1335-402B-01	76.0/24.0	27619Y4601-01	2.553	96.9	8.084	0.060	0.005
P/040-6	1060-402B-01	76.3/23.7	99253E4601-11	2.583	97.8	8.173	-0.047	0.069
P/040-7	1335-402B-01	76.0/24.0	27619Y4601-02	2.553	96.9	8.106	0.058	0.028
P/040-8	2236-402A-01	76.2/23.8	27643E2601-01	2.567	97.3	8.182	-0.080	0.089
P/040-9	2236-402A-01	76.2/23.8	27643E2603-02	2.582	97.8	8.096	0.067	0.019
P/040-10	2236-402A-01	76.2/23.8	27643E2603-01	2.582	97.8	8.054	0.061	0.018
P/040-11	2236-402A-01	76.2/23.8	27643E2602-01	2.586	98.0	8.121	0.082	0.011
P/040-12	2236-402A-01	76.2/23.8	27643E2602-02	2.586	98.0	8.096	0.071	0.040
P/081-1	4124-402B-01	75.8/24.2	27627Y4603	2.574	97.9	16.418	-0.084	0.062
P/081-2	4124-402B-01	75.8/24.2	27627Y4602	2.580	98.1	16.231	0.092	0.095
P/081-3	4189-402B-01	75.9/24.1	27709Y4601	2.580	98.0	16.347	0.050	0.015
P/081-4	4189-402B-01	75.9/24.1	27709Y4602	2.578	98.0	16.347	-0.059	0.032
P/081-5	4192-402B-01	76.0/24.0	27709Y4608	2.577	97.8	16.230	0.107	0.061
P/081-6	4192-402B-01	76.0/24.0	27709Y4607	2.576	97.8	16.380	0.092	0.114
P/081-7	4192-402B-01	76.0/24.0	27709Y4606	2.582	98.0	16.289	0.074	0.050
P/081-8	4189-402B-01	75.9/24.1	27709Y4604	2.580	98.0	16.370	0.051	0.132

[a] *Negative sign denotes center lagging lens*

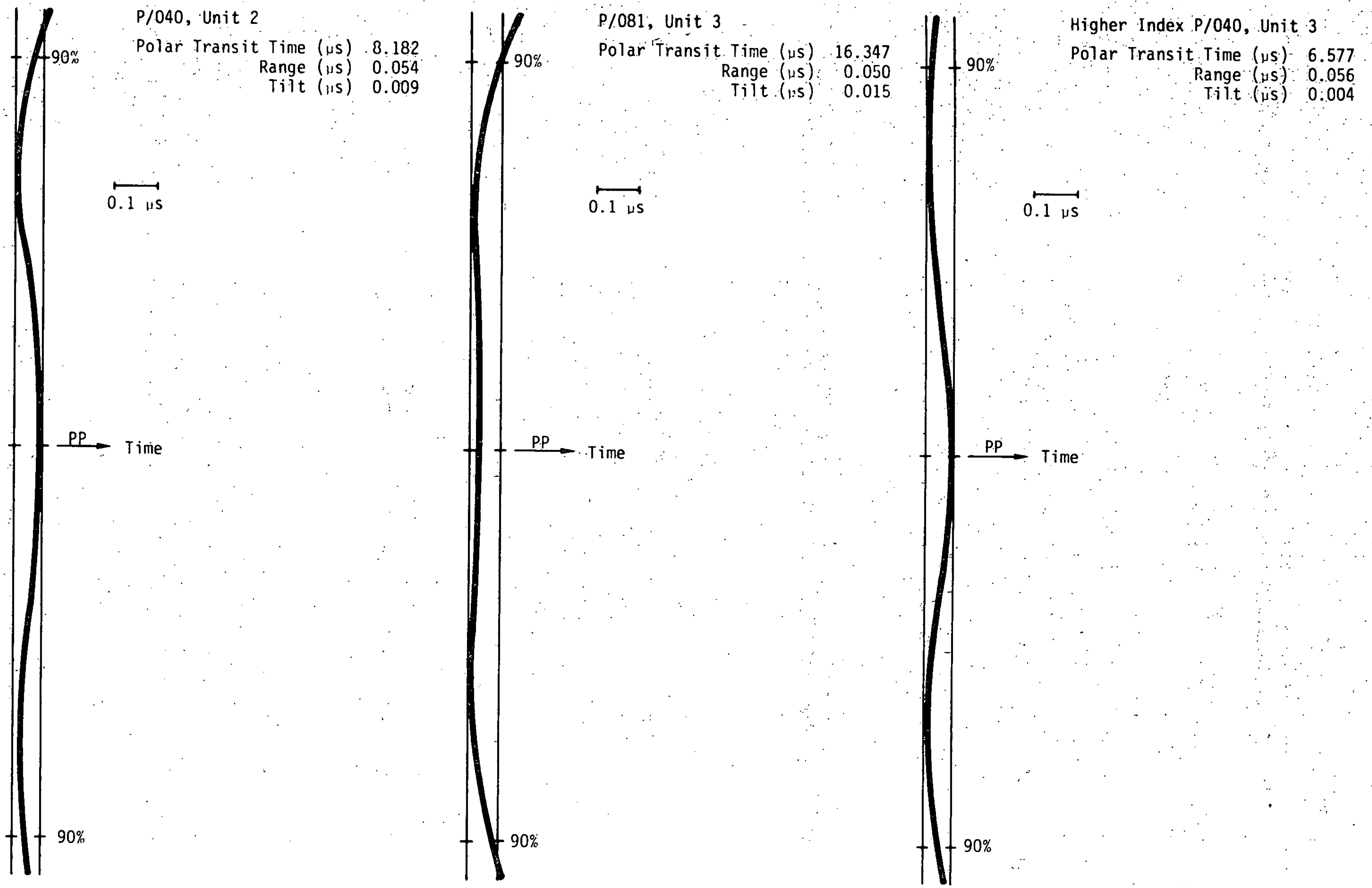
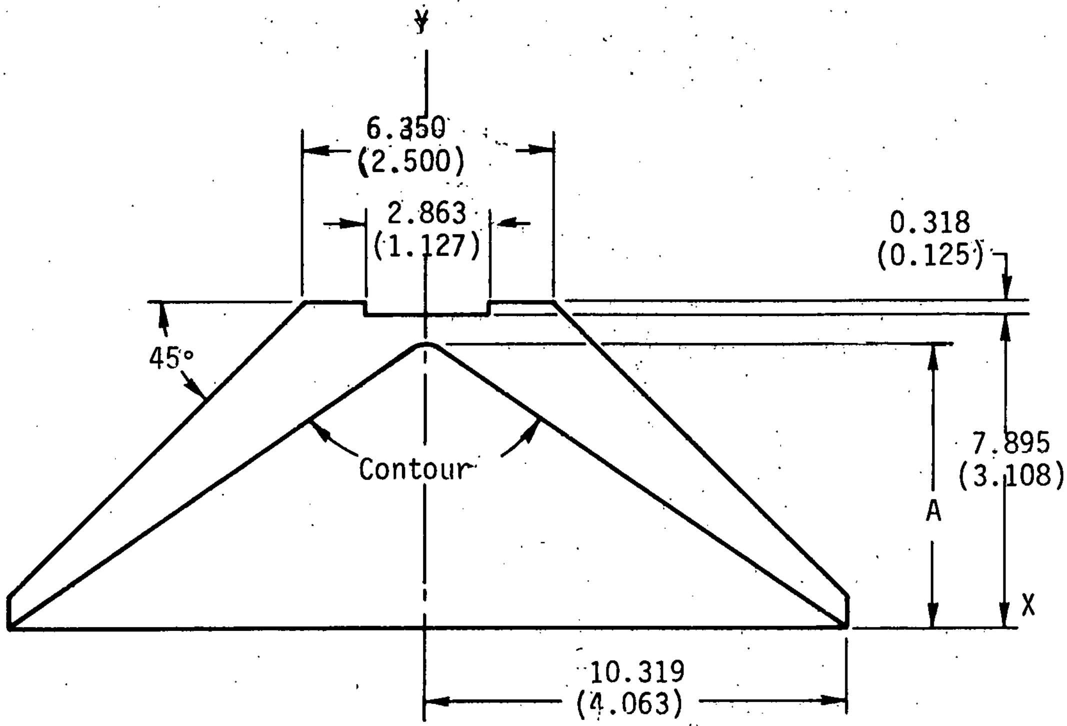


Fig. 2. Plane Wave Lens Test Fire Results



Dimensions in Centimeters, English Equivalents in Parentheses.
Contour Equations are in English Units

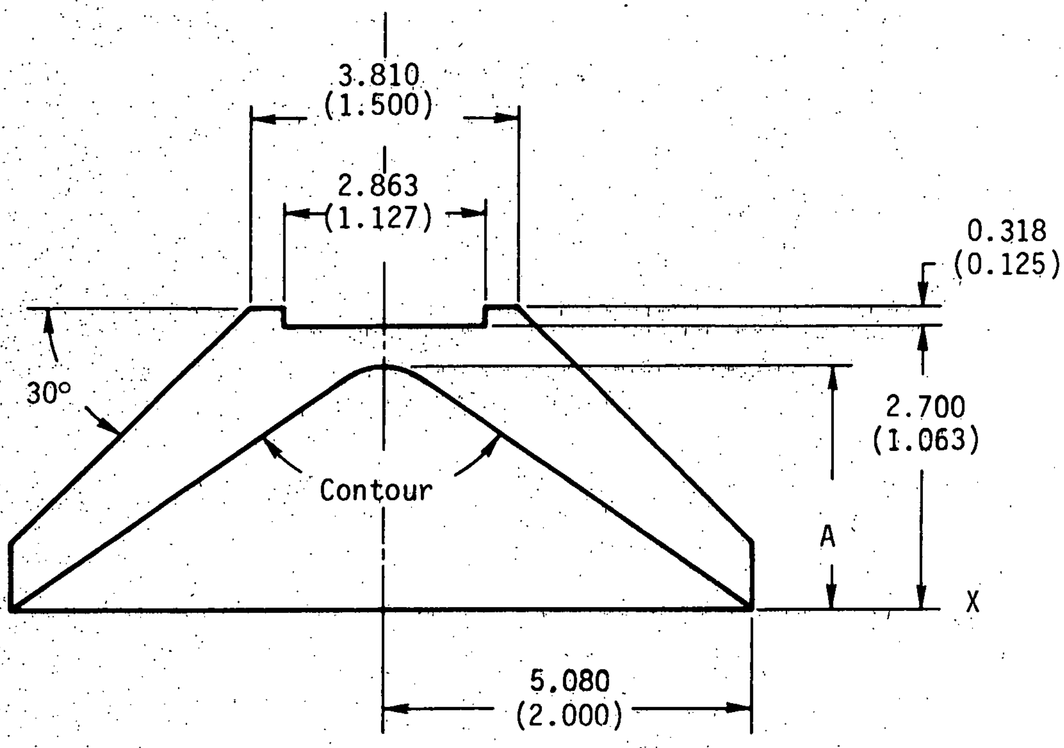
Original Contour Equation:

$X^2 = 1.949449Y^2 - 11.353103Y + 16.503906$
$A = 7.1057\ (2.7975)$

Final Contour Equation:

$X^2 = 1.757036Y^2 - 10.780181Y + 16.503906$
$A = 7.4526\ (2.9341)$

Fig. 3. P/081 Lens Design Using Pressable Comp B-3 and 76/24 BN/TNT Baratol



Dimensions in Centimeters, English Equivalents in Parentheses
Contour Equations are in English Units

Original Contour Equation:

$$X^2 = 4.091387Y^2 - 8.095279Y + 7.000$$
$$A = 2.4300\ (0.9567)$$

Final Contour Equation:

$$X^2 = 2.739587Y^2 - 6.762611Y + 4.000$$
$$A = 2.4961\ (0.9827)$$

Fig. 4. P/040 Lens Design Using PBX 9404 and 85/15 BN/TNT Baratol

Table II. Higher Index Plane Wave Lens Test Fire Results

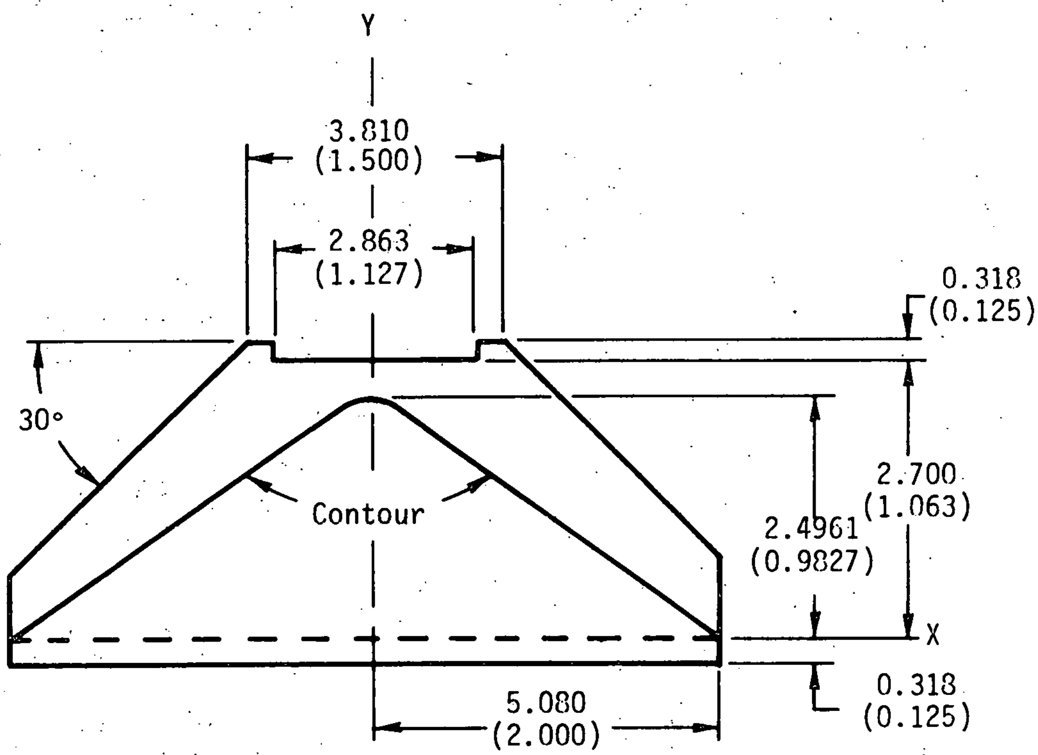
Plane Wave Lens No.	Baratol Batch No.	Composition (BN/TNT)	Baratol Piece No.	Density (Mg/m^3)	TMD (%)	Transit Time (μs)	Range[a] (μs)	Tilt (μs)
P/040-1	3339-402B-01	84.5/15.5	27465Y2603-01	2.765	98.0	6.523	-0.028	0.025
P/040-2	3339-402B-01	84.5/15.5	27465Y2603-02	2.765	98.0	6.623	-0.056	0.054
P/040-3	3339-402B-01	84.5/15.5	27534Y2604	2.745	97.3	6.577	-0.056	0.004
P/040-4	4325-402B-01	85.3/14.7	82737Y2402-1	2.763	97.3	6.522	-0.086	0.008
P/040-5	4325-402B-01	85.3/14.7	82737Y2402-3	2.764	97.3	6.535	-0.097	0.006
P/040-6	4325-402B-01	85.3/14.7	82737Y2403-1	2.753	96.9	Lost	-0.093	0.016
P/040-7	4325-402B-01	85.3/14.7	82737Y2403-2	2.751	96.9	6.546	-0.100	0.009
P/040-8	4325-402B-01	85.3/14.7	82737Y2403-3	2.753	96.9	6.471	-0.095	0.003
P/040-9	4325-402B-01	85.3/14.7	82737Y2404-1	2.756	97.1	6.528	-0.094	0.016
P/040-10	4325-402B-01	85.3/14.7	82737Y2404-2	2.765	97.4	6.518	-0.084	0.031

[a]*Negative sign denotes center lagging lens*

Table III. Modified Higher Index Plane Wave Lens Test Fire Results

Plane Wave Lens No.	Baratol Batch No.	Composition (BN/TNT)	Baratol Piece No.	Density (Mg/m^3)	TMD (%)	Transit Time (μs)	Range[a] (μs)	Tilt (μs)
P/040-M-1	4122-402B-01	84.9/15.1	82585Y2401-01	2.761	97.6	7.137	-0.144	0.066
P/040-M-2	4131-402B-01	85.2/14.8	82565Y2402-01	2.770	97.6	7.178	-0.195	0.089
P/040-M-3	4131-402B-01	85.2/14.8	82565Y2402-02	2.770	97.6	7.200	-0.207	0.101
P/040-M-4	4122-402B-01	84.9/15.1	82585Y2401-02	2.761	97.6	7.355	-0.229	0.121
P/040-M-5	4131-402B-01	85.2/14.8	82635Y4602	2.715	95.7	7.405	-0.316	0.056
P/040-M-6	3339-402B-01	84.5/15.5	27534Y2603-01	2.752	97.6	7.146	-0.118	0.047
P/040-M-7	3339-402B-01	84.5/15.5	27465Y2604-01	2.764	98.0	7.162	-0.167	0.083
P/040-M-8	3339-402B-01	84.5/15.5	27465Y2604-02	2.764	98.0	7.178	-0.145	0.056
P/040-M-9	3339-402B-01	84.5/15.5	27534Y2603-02	2.752	97.6	7.194	-0.164	0.035
P/040-M-10	4325-402B-01	85.3/14.7	82737Y2401-01	2.772	97.6	LOST	-0.123	0.014

[a]*Negative signs denotes center lagging lens*



Dimensions in Centimeters, English Equivalents in Parentheses.
Contour Equations are in English units.

Contour Equation:

$$X^2 = 2.739587Y^2 - 6.762611Y + 4.000$$

Fig. 5. Modified Higher Index P/040 Lens Design

During testing these lenses were viewed at a 45° angle of incidence to the streak camera. As the shock wave progressed into the PETN the reacting particles showed as spray lines on the streak record. This allowed calculation of the free surface velocity of the baratol. Since free surface velocity is related to pressure these values of velocity were used to give relative pressure values at various points across the surfaces of the lenses. It should be noted that absolute pressure calculations could not be made since the shock velocities were not measured.

These tests indicated no significant differences in the pressure profiles of the various lens designs. Numerical values of the free surface velocities agreed very well between the overcast and pressable Comp. B-3/baratol lenses. The free surface velocities of the PBX 9404/baratol P/040's were about 25% higher than those of the Comp B-3/baratol lenses. However, the output pressure should be approximately the same in both cases because of the difference in shock velocities of the two baratols. In all cases the pressure profile was slightly "bat-wing" shaped with the lowest pressures occurring at the center and edges of the lenses. The mid-diameter region was approximately 20% higher in pressure.

COMMENTS, CONCLUSIONS

Results of the P/040 plane wave lens given in Table I show very good reproducibility. Some of the lenses were leading at the centerline while the rest were lagging. This indicates that not much more could be done to improve this lens design. The transit time of Unit No. 8 was slightly out of specification with the other lenses made from that baratol batch. All the other lenses were well within transit time specifications.

In the case of the P/081 plane wave lenses shown in Table I, Unit No. 5 slightly exceeded the range specifications. The other seven lenses were within the range specifications. However, transit time specifications were exceeded in two of the three baratol batches. This indicates more stringent controls are necessary in pressing, machining and assembly. Since the baratol compositions were good and the ranges agree fairly well, it is thought that this is an acceptable lens design.

Higher index P/040 results shown in Table II indicate both transit time and range specifications were met. All of these lenses were lagging slightly at the centerline.

None of the modified higher index lenses were within specifications. Unit No. 5 yielded a range of 0.316 μs while the others were approximately 0.15 to 0.20 μs. This is a good example of the effect of low density baratol. All of these lenses were lagging at the centerline by almost the full amount of their ranges. The output traces were "V"-shaped whereas typical traces of the previous mentioned lenses were somewhat "bat-wing" shaped.

Results of pressure profile measurements show no advantage of one lens system over the others. However, the higher index lenses have a significant size advantage.

In considering the results of the modified higher index lenses with those of pressure profile measurements it seems reasonable that the modified lenses would be lagging in the center region. The lower pressure at the center of the lens, at the point of the original output surface, would produce a slower shock through the center of the extra thickness of baratol on the lens face. The pressure profile of the higher index lens, and the other lenses for that matter, could probably be improved by adjusting the interface contour to give a nearly simultaneous breakout at this new surface. The smoothness of the pressure profile would then be a function of the extra thickness of material on the output surface and of the lens system involved.

This is the final report on plane wave lens development using pressable rather than cast explosives. This work has demonstrated that a PWL can be produced from pressable explosives if the need arises.